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A New Underground Air Traffic Control Centre for Oslo

Bård Bakkejord and Jan B. Høyer

Abstract—*The Civil Aviation Administration of Norway (NCAA) is currently undertaking a comprehensive programme for the modernization and enhancement of air traffic control services in southeast Norway. The most important element within this programme is the establishment of a new Air Traffic Control Centre (ATCC) for Oslo that will provide both area and approach control services within the area. A national air traffic control school (the ATS Academy), which will provide both basic and advanced training for air traffic controllers, will be established in conjunction with the ATCC. The facility will also provide for maintenance, development and testing of application software and system enhancements. The ATCC is sited underground, and administration and training facilities are in buildings outside, connected to the air traffic control centre by a tunnel. The paper describes the major operation systems and sub-systems that will support the ATCC activities.*

Résumé—*L'Administration de l'Aviation Civile de Norvège (NCAA) a entrepris un vaste programme de modernisation et de développement des services de contrôle du trafic aérien pour le sud-est de la Norvège. L'élément le plus important de ce programme est la mise en place d'un nouveau Centre de Contrôle du Trafic Aérien (ATCC) pour Oslo, qui assurera les services de contrôle aussi bien local que d'approche pour ce secteur. Une école nationale de contrôle du trafic aérien (Académie ATS) sera créée en relation avec l'ATCC. L'installation assurera l'entretien, le développement et le contrôle des logiciels et des systèmes. L'ATCC est implanté en souterrain, et les locaux administratifs et de formation se trouvent dans des bâtiments extérieurs, reliés au Centre par un tunnel. L'Académie ATS assurera une formation de base ainsi que des stages de perfectionnement pour les contrôleurs du trafic aérien. L'article décrit les principaux systèmes et sous-systèmes d'exploitation sur lesquels s'appuieront les activités de l'ATCC.*

Project Information—Summary

The Civil Aviation Adminstration of Norway (NCAA) is currently undertaking a comprehensive programme to modernize and enhance its air traffic control services in southeast Norway.

The most important element of this programme is the establishment of a new Air Traffic Control Centre (ATCC) for Oslo FIR (the Oslo Flight Information Region). The Oslo ATCC will provide both area and approach control services within the area (see Fig. 1).

A national ATS (Air Traffic Services) Academy will be established in conjunction with the ATCC. The ATS Academy will use the ATCC Simulator for both basic and advanced training of air traffic controllers. The facility will also provide for maintenance, development and testing of application software and system enhancements.

The air traffic control centre is situated underground.

Administration and training facilities will be housed in outside build-

Figure 1. The new Oslo Air Traffic Control Centre houses 41 work stations for air traffic controllers in a rock cavern facility.

Present address: Bård Bakkejord and Jan B. Høyer, PABAS Consulting Engineers and Architects, Bærumsveien 375, P.O. Box 23, 1346 Gjettum, Norway.

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ings, which will be connected to the air traffic control centre by a tunnel.

The major operation systems supporting the air traffic control (ATC) activities include:

- The operational ATC system, which encompasses radar data and flight plan data-processing sub-systems.
- The ATS simulator system.
- The Voice Communication System.
- The Operational Information System (OPS).

Sub-system integration and control will be managed by a control and monitoring system. All sub-systems will provide for a high degree of automation, and will meet strict availability requirements.

The inherent system capacities and flexibility, coupled with expansion capabilities, will ensure that the new Oslo ATCC will have the necessary capacity to handle projected growth in air traffic safely and efficiently, well into the next century.

The mission of the Oslo ATCC system is to:

- Enhance the safety of air travel through the timely acquistion and presentation of flight-related data for use by air traffic controllers and support staff.
- Support the training of air traffic controllers and support staff.
- Support the maintenance, development and testing of application software, as well as evaluation of revised operational procedures.

The Oslo ATCC system will be composed of the following sub-systems:

1. The ATCC Operational System (OPS), comprising a central complex and interactive ATS units.
2. The ATS Simulator System.
3. A Control and Monitoring System.
4. A Software Maintenance and Development System.

Project Description

Air traffic in Norway, measured in numbers of passengers, has increased by 82% over the last ten years. A total of 16.1 million passengers travelled through Norwegian airports in 1991.

The Civil Aviation Administration owns, operates and maintains 19 primary airports in Norway, some of them in cooperation with the Ministry of Defense. In addition, the CAA is responsible for overall planning of non-state-owned airfields (secondary airfields, short runway airfields and others).

Oslo ATCC, the new control centre at Røyken (see Fig. 2), replaces the existing control centre at Oslo's Fornebu Airport.

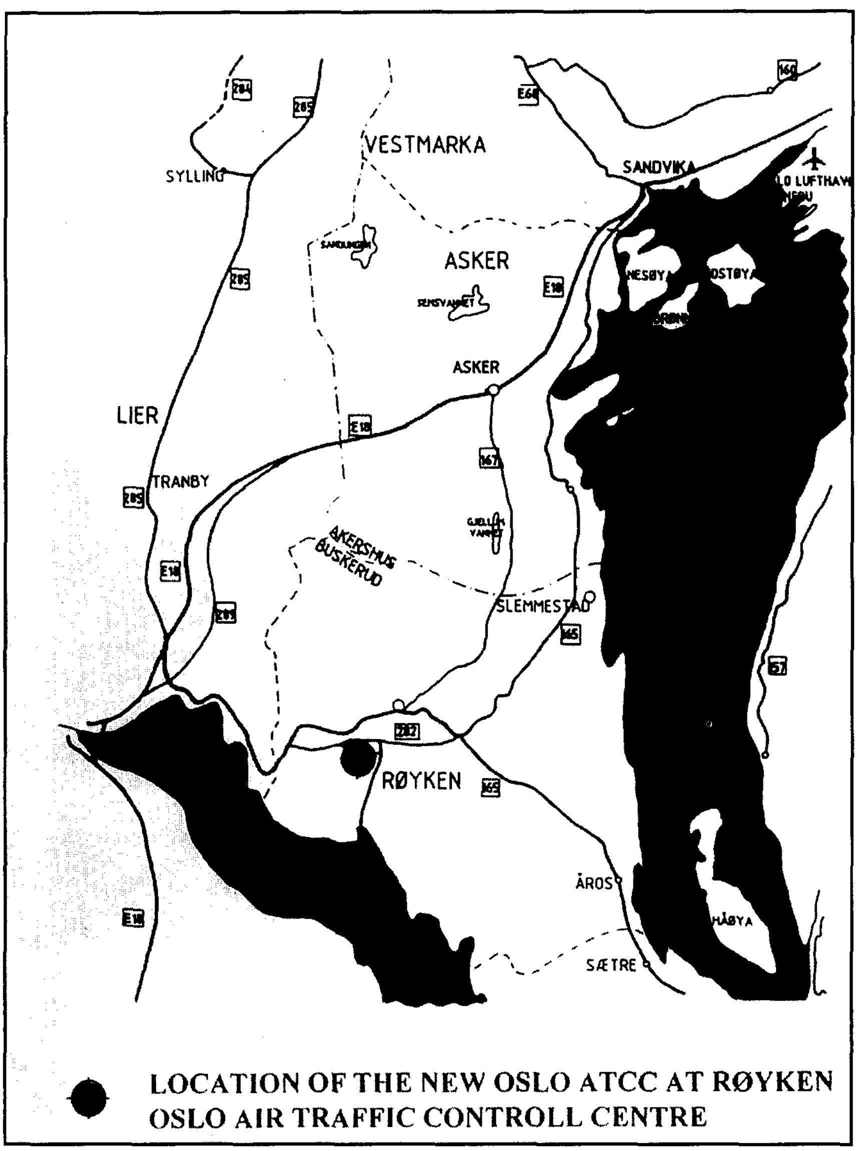


Figure 2. The new Oslo Air Traffic Control Centre at Røyken will replace the control centre at Oslo's Fornebu airport, shown at the upper right of the figure.

Progress of the Construction

In November 1987, the Ministry of Transport directed the Norwegian Building and Estate Department (SBED) to carry out construction of the new Oslo Air Traffic Control Centre. The assignment was based on a proposal for a room programme to be prepared by PABAS engineering firm, on instructions of the Civil Aviation Administration of Norway (NCAA).

A project team consisting of representatives from SBED, CAA, TRF (Norwegian Telecommunications for Design of Aircraft Navigations), and PABAS was established in October 1988.

The formal application for building license was forwarded to the authorities on March 1989, and the extensive blasting and excavation works began in August 1989.

The building license was issued on January 26, 1990. Building operations began in June 1990 and were completed and approved on March 1992. CAA took possession of the buildings on April 1, 1992.

The Civil Aviation Administration of Norway is responsible for radar, data and communication installations in the buildings. These systems were installed in the autumn of 1992 and an initial trial run of the simulator was performed in January 1994. The Oslo ATCC facility is expected to be fully operational in July 1995.

Construction Works

Basis for Planning of Facilities

The Oslo ATCC at Røyken comprises the following six administrative and operation functions:

1. *Administration Region Røyken*: Air traffic control for eastern Norway.
2. *Oslo ATCC*, which includes educational and training facilities in this connection.

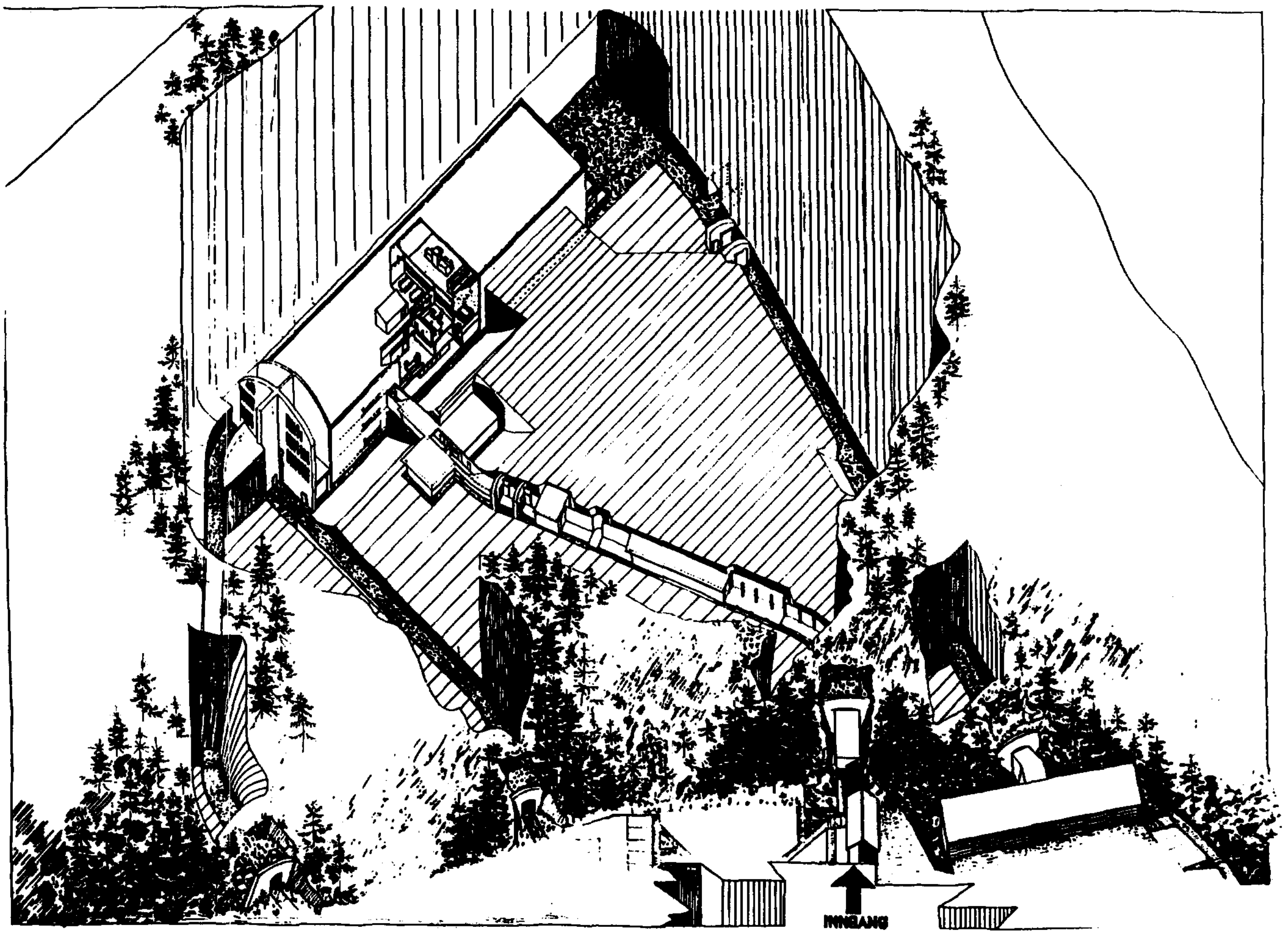


Figure 3. Oslo Air Traffic Control Centre: view of the building in the rock cavern.

3. *ATS School*: Air traffic control school for Norway.

4. *ETATS School*: covers all activities within Civil Aviation Administration of Norway.

5. *CAA Air Navigation Department*: Operation and maintenance of data, radar information and communications equipment.

6. *Operation and maintenance functions* related to the facilities.

Location

Independent of the selection of a final location for a new Oslo airport, the new Oslo ATCC was located at Røyken, west of Oslo. The main access is by main highway RV 282 to Røyken.

Design of the Buildings

The design of the facilities has been based on cost-effectiveness studies, taking into consideration both investment costs and the costs of operation and maintenance. Recognized and tested technical solutions for construction materials and finish have been chosen.

The buildings have been designed with construction flexibility in mind: i.e., expansion possibilities, as well as possibilities for rearranging the layout within the given limitations. Therefore, the rock cave created by excavation is large enough to allow for considerable expansion.

The main access to the facilities is through the central hall in the Administration building, with connection to the control centre in rock through an access tunnel.

The main functions of the ATCC, i.e., the **control room** with associated support facilities, are located in rock for protection purposes. This underground building portion of the ATCC is three stories deep (see Figs. 3, 4 and 5). The base area of the cave is approx. 2600 m^2.

The parts of the ATCC that do not need fortification protection are placed in the **administration building**, which is located outside the rock, but adjacent to the protected facility (see Fig. 6). The three-story-high administration building has a base area of approx 1810 m^2.

A building with accommodation facilities has been constructed for external CAA personnel staying at the center for longer periods. This **personnel quarters** building is located near the entrance to the site. The two-story building has a base area of approx. 665 m^2.

The **garage building** has a base area of 325 m^2.

Costs of construction for the project are given in Table 1. Table 2 gives the areas and volumes of spaces for the facility that were created by blasting.

Connection Tunnels

In order to ensure that the ATCC would function according to intentions and requirements, it was necessary to construct **connection tunnels** between the different parts of the facility (see Figs. 7 and 8).

The main access to the ATCC is a corridor-type tunnel from the Administration building.

Access to support functions has been provided as a service tunnel directly from the outside, so that maintenance and repair work will not interfere with normal operation of the control centre. The maintenance tunnel can be used by cars.

In addition to this maintenance tunnel, other tunnels have been constructed for ventilation purposes (see Fig. 9).

Structural Systems

The **rock cave** area (Fig. 10) is primarily composed of Drammensgranitt, a strong red granite. The strength of the rock has been decisive for the choice of width and shape of the

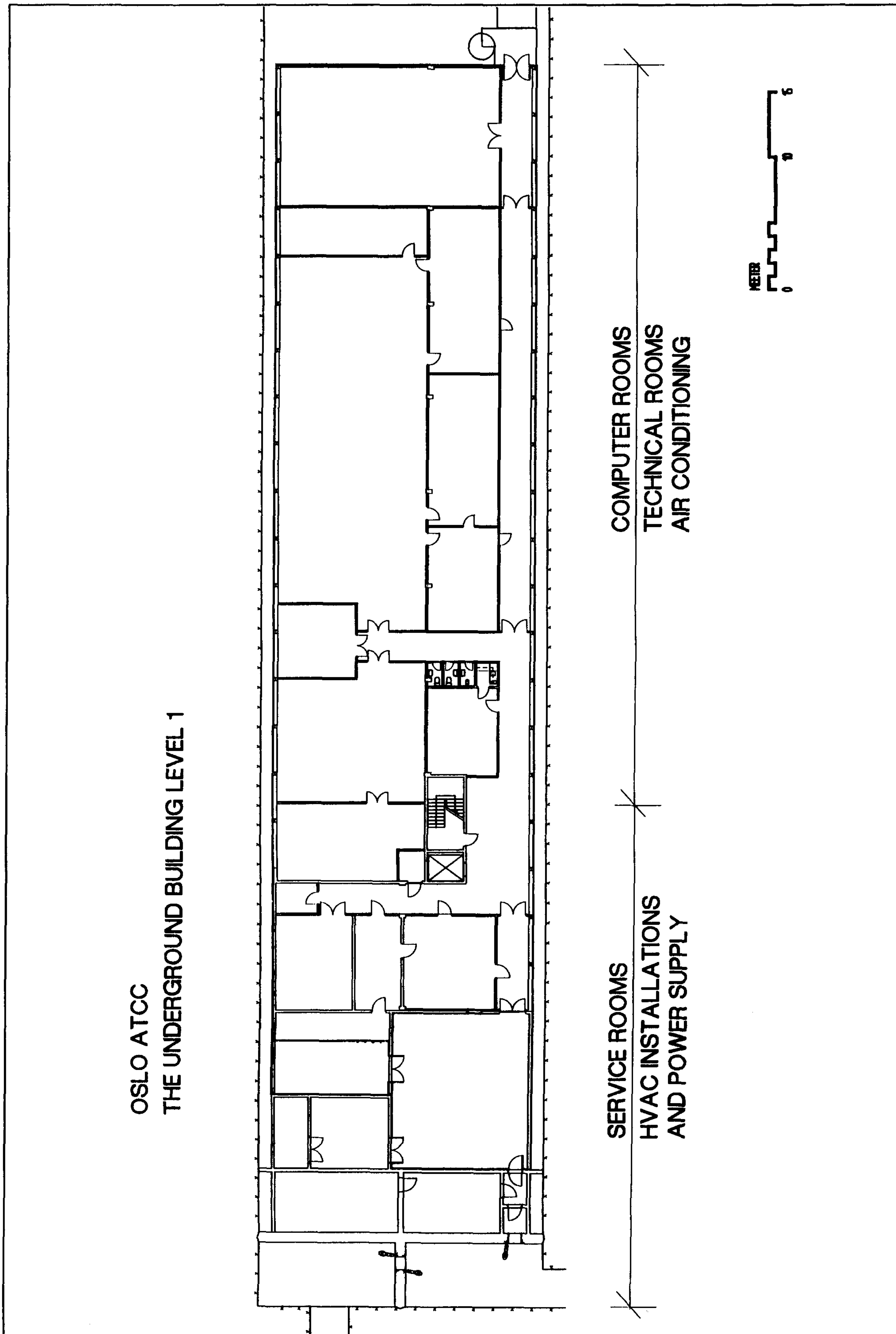


Figure 4. Underground building level 1 of the Oslo Air Traffic Control Centre.

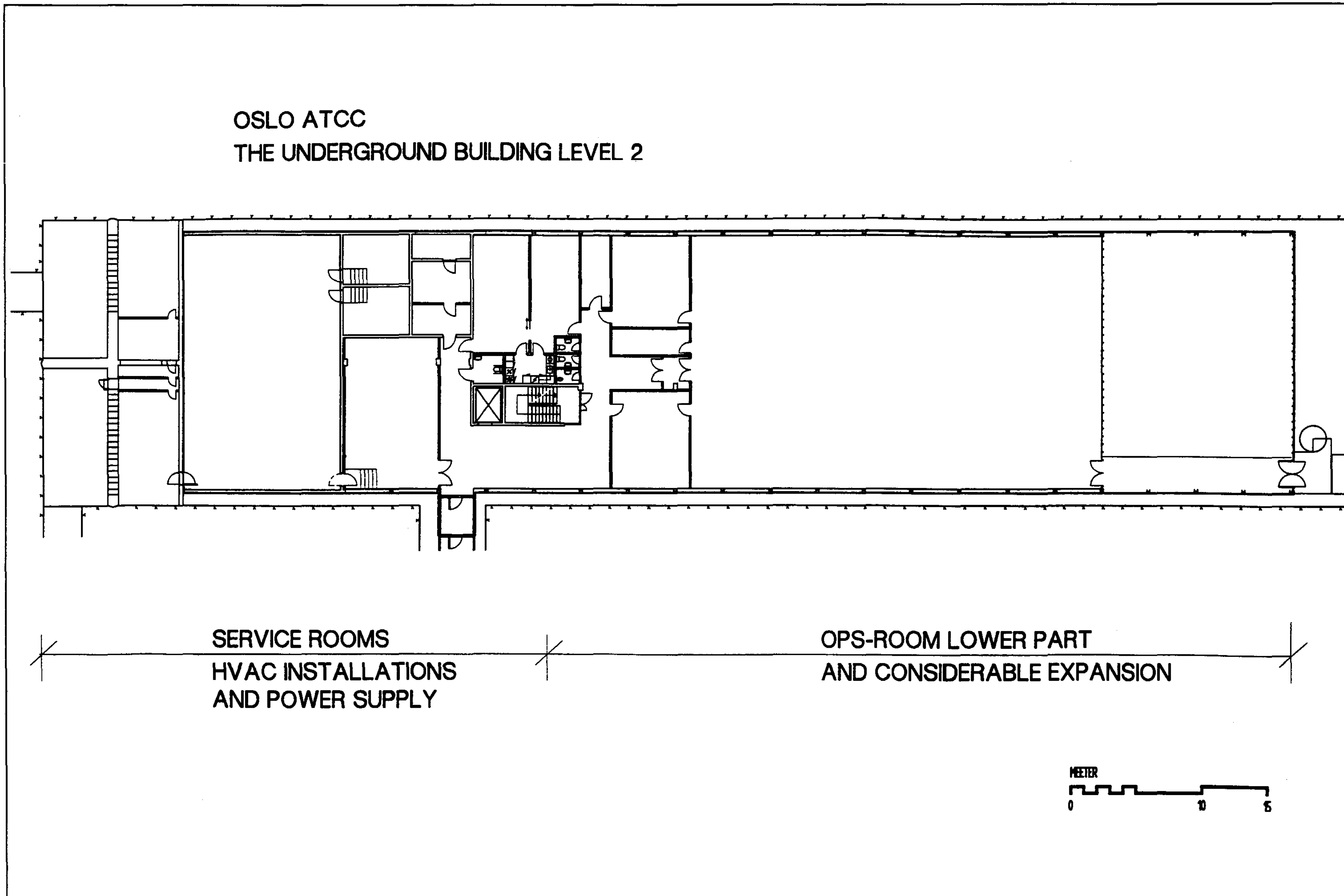


Figure 5. Underground building level 1 of the Oslo Air Traffic Control Centre.

Figure 6. The completed administration building for the Oslo ATCC is aboveground, adjacent to the underground control centre facility.

excavation. The main cave has been placed in an area with no observed zones of weakness. The predominant direction of the excavation is approx 45° on the direction of the main cracks.

The permanent rock support is based on systematic rock bolting, combined with 10 cm of shotcrete. There has been no need for heavy concrete lining.

Columns and beams in the middle of the **underground building in rock** are made of prefabricated concrete elements. The intermediate slabs and roof slab are made of prestressed concrete elements.

The complete building has been enclosed in an envelope of Corten-steel to obtain full EMP shielding.

The structural system of the **administration building** is formed by prefabricated concrete elements. Intermediate slabs and the roof slab area are supported on beams and columns. Wind forces are distributed by the slabs to the walls around stairways and end-walls of the building.

The **auditorium building** is made of reinforced concrete poured *in-situ*. The roof is supported on frames of laminated wood.

The **personnel quarters** building also has been provided with a structural system of reinforced concrete poured *in-situ*. However, the roof support slab is made of prefabricated concrete elements. The roof is made of wood.

Fire Risk Evaluation of Building in Rock

The functions of the underground control centre part of the facility are very important to air traffic in peacetime, as well as in war. Generally, the building is fireproof and the furniture and equipment do not represent a large fire load. To the greatest extent possible, the finishes are made of non-combustible and fire-retardant materials, which will not emanate any toxic gasses in case of fire.

The building has been provided with a fire-alarm system, and the most important rooms have been equipped with halon fire-extinguishing systems. The electric cables are non-combustible and non-toxic.

There are four exit tunnels that can be used for fire escape.

HVAC Installations

HVAC installations for the administration building and the underground building in rock are not interconnected, but instead act as totally independent units.

The philosophy behind both the planning process and the choice of

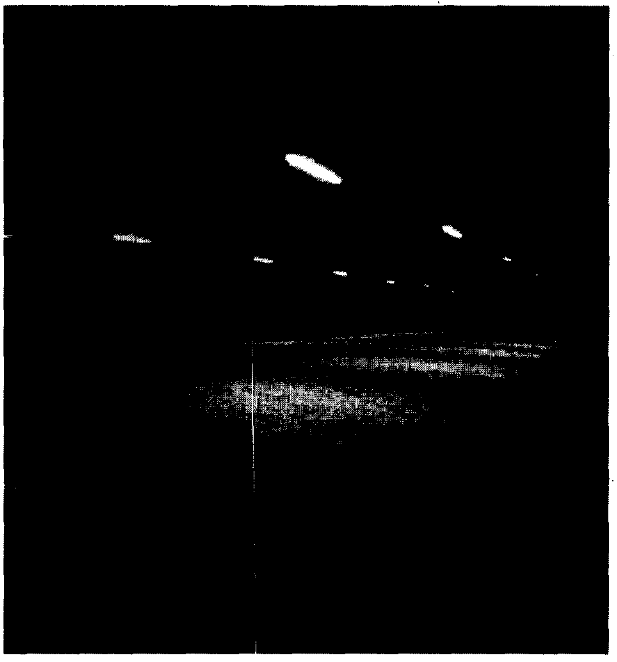
Table 1. Approximate costs of construction for the Oslo ATCC project.

Project Structure	Cost (approx.) *
Rock cavern	18 million NOK
Building in rock	102 million NOK
Aboveground buildings (outside)	130 million NOK

Note: NOK - $US conversion factor .154

Table 2. Blasting performed for underground portions of the Oslo ATCC project.

Portion of Underground Work	Area (approx.)	Volume (approx.)
Main access	21 m²	2500 m³
Service access	26 m²	2800 m³
Ventilation tunnels	10 m²	46,500 m³
Rock cavern	390 m²	6500 m³
Roads, areas (approx.)		7,000 m³



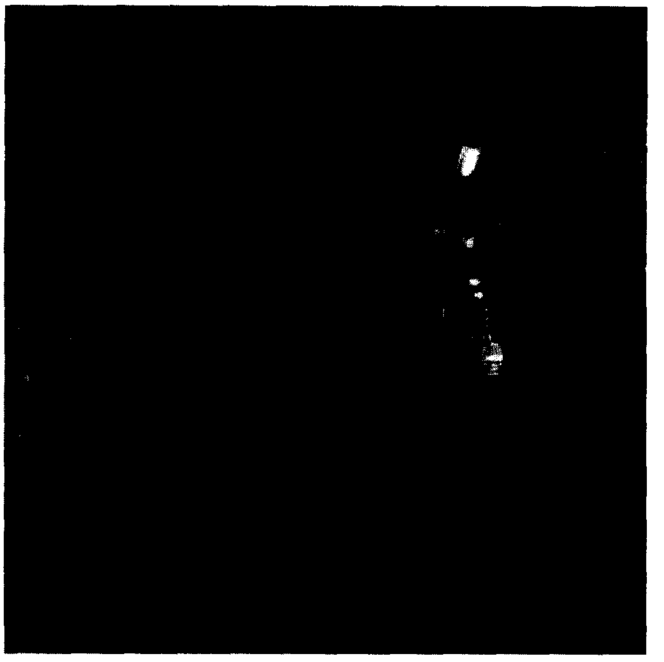


Figure 7 (left): Main access tunnel to the underground portion of the Air Traffic Control Centre. Figure 8 (right): The service tunnel will allow maintenance and repair work to be performed without interfering with normal operations of the Control Centre.

HVAC systems emerged in close cooperation with the users. The most important obejctive was to create a technical installation that would ensure continuous operation and which would, at the same time, be flexible with regard to future alterations. Other considerations were easy maintenance and energy efficiency.

Flexibility has been achieved to a great extent by separating ventilation, heating and cooling systems and by using standardized components.

Heat recovery and free cooling facilities have been introduced where feasible. Waste heat from water chillers is used to cool ventilation air.

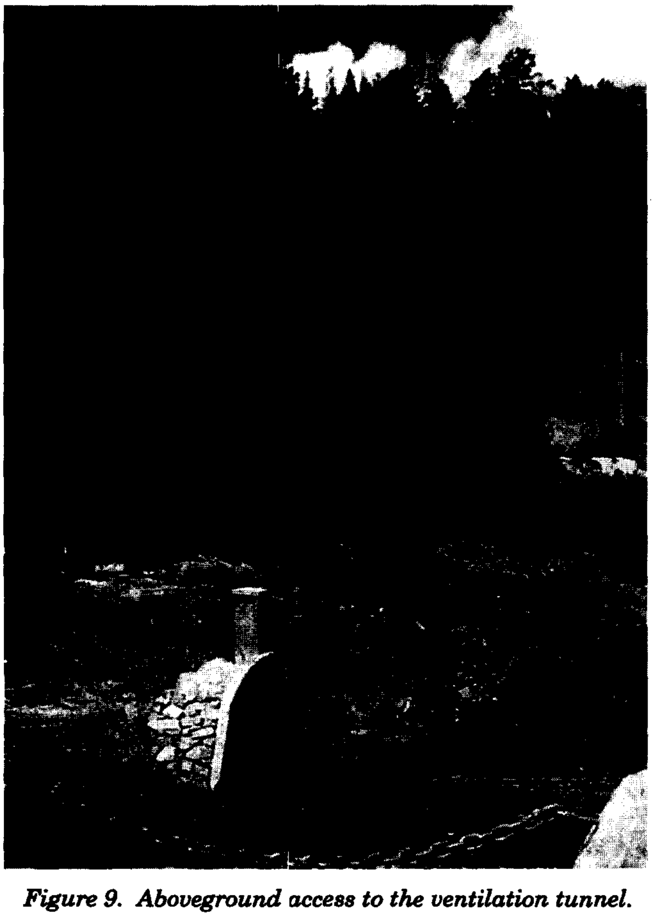


Figure 9. Aboveground access to the ventilation tunnel.

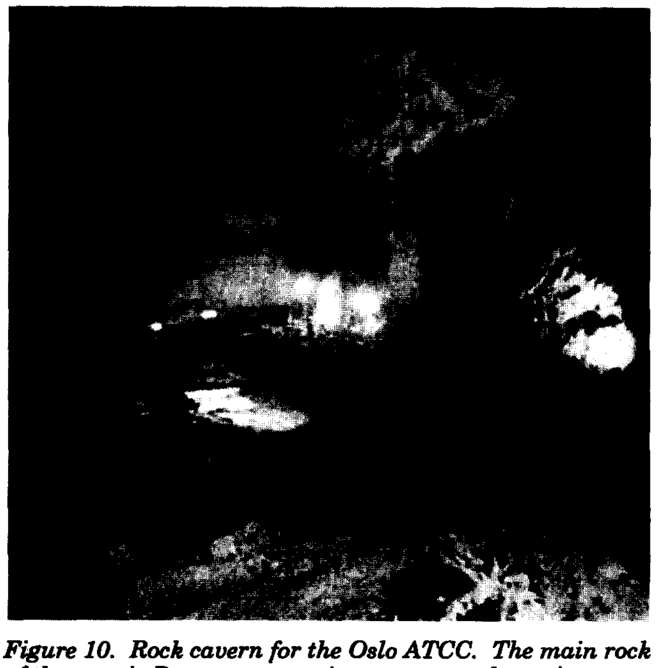
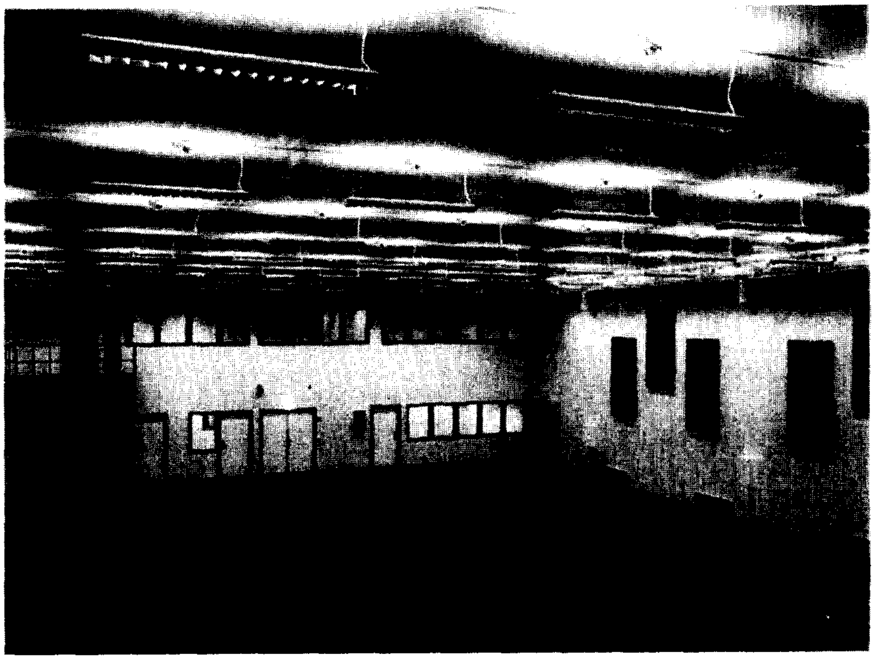


Figure 10. Rock cavern for the Oslo ATCC. The main rock of the area is Drammensgranitt, a strong red granite.



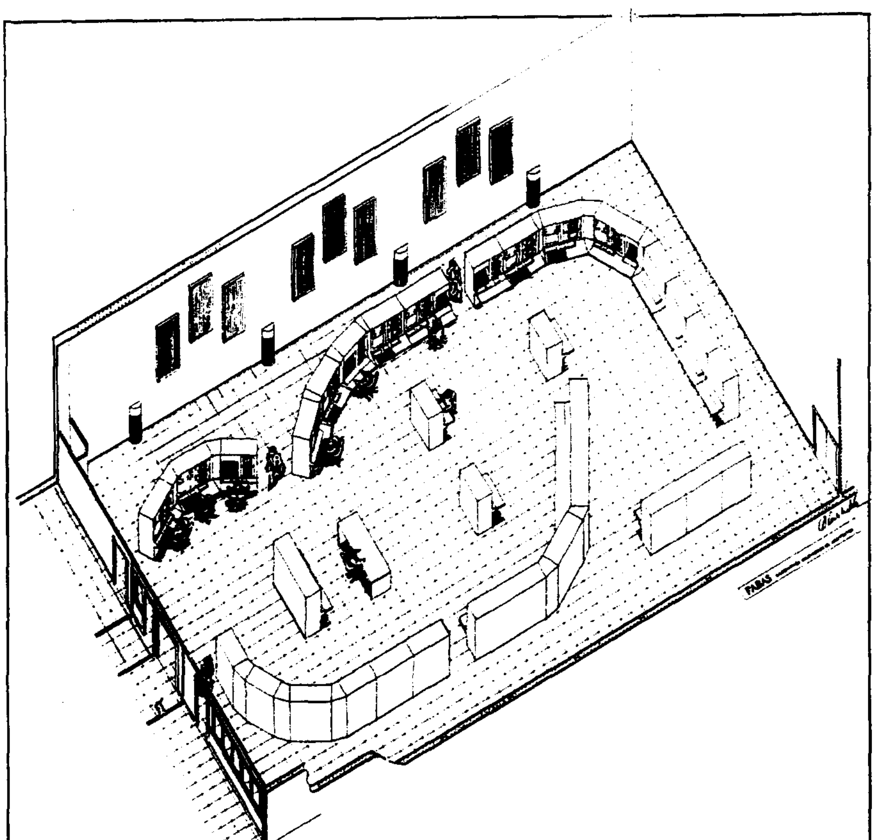


Figure 11 (top), and Figure 12 (bottom): The OPS (operational system) Centre, after completion and in plan.

Cooling System

Ventilation air for technical facilities in rock cavern building is cooled by means of chilled water produced in three chiller units.

Chilled water is distributed to cooling coils, fan coils, cooling ceilings and room coolers throughout the building, in areas where cooling is required.

The condenser circuits of the water chillers are cooled by three axial fans, with variable pitch angles, which draw outside air through the condenser coils.

A similar cooling system with two chiller units has been installed in the Administration building.

Air Conditioning

The OPS (operational system) Centre is totally air-conditioned, with fully developed temperature and humidity controls (see Figs. 11 and 12). Ventilation air is supplied at a constant rate at conditions of 20°C and 50% relative humidity.

Heat loads in the different rooms are removed through the use of chilled water recirculating through fan coils or cooling ceilings. The generator room, UPS room and other power rooms are cooled by large room coolers recirculating and cooling the room air.

Heating System

The Administration building is heated by convectors, installed on the perimeter wall and supplied with hot water between 70°C and 90°C. Hot water is produced in a combined electrical/oil fired boiler.

The rock cavern building is heated by small electric panel heaters.

Central Vacuum Cleaning System

Both buildings are furnished with a central vacuum cleaning system.

Floor-mounted inlets have been placed to cover all areas and are connected to a central unit via welded steel pipes. The installation can be used for both dry and wet cleaning.

Sanitary Installations

The buildings are connected to the domestic water and sewage system in Røyken. A new 2-km-long connection to the existing facilities in Røyken town centre was a part of the project. Furthermore, sanitary installations and water supply have been provided in accordance with standard Norwegian regulations.

Building Automation

Direct digital control-type electronic control devices have been installed for building automation purposes.

The autonomic subcentrals are connected to a central monitoring system, with one work station in each building. More than 2000 points are connected to the system and available on the screen.

The central monitoring system also incorporates a programme for automatic status and alarm transmittal to external subscribers via modem.

Ventilation System

Conditioned air is supplied to the various rooms in accordance with Norwegian regulations. No recirculation of air takes place. Heat recovery is performed by means of water circulating between air inlet and outlet coils.

The administration building is provided with four air-handling units that supply conditioned air. The ventilation system is divided up to satisfy different requirements in the various parts of the building.

Air is supplied to the different rooms using ceiling-mounted diffusors. In the operation and control rooms, the air is supplied using the low-impulse method, i.e., slightly chilled air supplied through floor-mounted diffusors.

The rock cavern building ventilation system is dimensioned for secured operation. A reduced amount of air is supplied through gas-tight dampers and NBC filters. Most of the air is then revitalized and recirculated.

Fire Protection System

A separate smoke evacuation system has been installed in the rock cavern building. Its main task is to prevent smoke from entering the emergency exits. This is achieved by forced evacuation of air from the fire zone and by pressure control of the rest of the building.

Technical rooms and power supply room are equipped with a halon fire-fighting system. At the time of construction, this was the only suitable type of installation, since it is not permissible to disconnect the power supply in the event of a fire.

In addition, selected fire-resistant and non-toxic materials have been used throughout the installation to prevent the occurrence of poisonous gases.

Electrical Installations

Power supply

Electricity for the installations is provided by two substations.

The substation for the installations in the rock cavern building has two transformers, each rated at 800 kVA. The substation for buildings outside has one transformer rated at 800 kVA and another rated at 630 kVA. The latter provides power for heating purposes.

The distribution voltage is a 400-V, TN-S system.

An emergency power plant consisting of three diesel-electric units has been built for the rock cavern building installations and important technical equipment in the outside buildings. Each aggregate is rated at 700 kVA and covers 50% of the load.

This emergency plant also contains a UPS-installation to supply power to communications and computer equipment. The installation consists of three UPS-units connected in parallel. Each unit covers 50% of the load. The UPS units have a common battery bank, with a 100% load capacity or 530 kVA for 30 minutes.

For the main power distribution panels, plug-in circuit breakers are used. The main power panel for UPS-power supply has a double bus bar system to make servicing possible without cutting the power of any circuit.

Capacitors have been installed to correct the power factor, and a harmonic absorber filter has been placed on the primary side of the UPS.

Shielding

For EMP (Electromagnetic Pulse) protection, the main parts of the rock cavern building installations are located within a steel-shielded building and all metallic cables are protected by EMP filters. For this reason, the installations have an extensive grounding system.

Power Distribution

All of the main cables inside the buildings have been placed on cable ladders or are contained in cable ducts. The main equipment rooms have data floors wherein cable ladders and ducts are installed.

Lighting Installations

Throughout the planning process, great emphasis has been placed upon the importance of minimizing the operating expenses for all lighting installations.

For the operation and simulating rooms, and for rooms where data terminals are installed, special care has been taken to avoid glare and reflection on screens.

Cable Installations for Telecommunications and Data Equipment

A flexible cable system has been provided for all of the buildings.

Supporting Communication Systems

For both warning and general information purposes, a public address system covering all the buildings has been provided.

The maintenance department will have an additional internal telephone system, which will make it possible for a manager to reach various personnel whenever and whereever they are working.

Fire Detection and Fire Extinguishing System

All buildings are controlled by an automatic, analogue, addressable fire detection system. Each building has its own central unit that can alert the local fire brigade directly. Internally, an alarm from the central unit in one of the buildings also activates the central unit in the other buildings, so that alarms are sounded throughout the installations.

Displays have been installed at all central areas to advise people in the event that a fire has been detected.

For the most important technical rooms, halon extinguishing systems have been installed. However, these have been kept to a minimum and are only installed where other possible solutions are not available.

The halon systems are connected to the fire alarm central units to ensure that the alarm system cover the whole installation.

Control System

An access control system covers the entrance and other important doors. This is connected to an alarm central. In addition, an ITV-system has been installed. □